# A Study on Estimation of Cassava Area and Production Using Remote Sensing and Geographic Information Systems in the Northeast Region of Thailand



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# A Study on Estimation of Cassava Area and Production Using Remote Sensing and Geographic Information Systems in the Northeast Region of Thailand

Apisit EIUMNOH* and Rajendra P. SHRESTHA*

**Abstract**

A study on cassava plantation area and production was conducted in the northeast region of Thailand using an integrated Satellite Remote Sensing (SRS) and Geographic Information Systems (GIS). Although, SRS and GIS are considered as the efficient tools for resource inventorying and monitoring, little work has been done in Thailand with regards to the large area crop monitoring and production estimation. The objective of the study was to explore the use of NOAA-AVHRR data for mapping cassava plantation areas. GIS was employed to create geographical database, such as soils, topography, land use and also for improving the results of image classification. The study conducted for the two crop seasons of 1995 and 1996 indicated that the NOAA-AVHRR data can be used to map the cassava plantation areas at the regional scale in Thailand. The results of the study were compared with existing cassava statistics produced from the Thai Tapioca Development Institute (TTDI) and the Office of Agricultural Economics (OAE), Thailand. The estimated cassava plantation areas from the study were underestimated by − 9.7 and − 16.4 percent to that of TTDI and OAE, respectively for 1995 and overestimated by 4.0 percent but underestimated by − 14.4 percent, respectively for the year 1996.

## I Introduction

### I − 1 *Cassava Plantation in Thailand*

Cassava called as Tapioca (*Manihot esculenta* Crantz) is one of the major export crops of Thailand. There has been tremendous increase in cassava plantation area in the country in the last three decades, from 71,520 ha in 1960 to 1,228,111 ha in 1996 [OAE 1974; 1996, respectively]. Van der Eng [1998] mentioned that in the 1960s, Thailand took over Indonesian position as Asia's main cassava exporter. The crop gained considerable popularity among the Thai farmers because of the two main reasons: increased demand of cassava roots in the foreign market though the farm-gate price has been fluctuated over time, and the crop's excellent adaptability in the adverse climatic and biophysical condition. The crop performs well on poor upland soils, has high tolerance to drought, diseases and insect pests, and more importantly its flexible planting and harvesting times

* School of Environment, Resources and Development of the Asian Institute of Technology, P. O. Box 4, Klongluang 12120, Thiland

**Table 1** Plantation Area, Yield and Production of Cassava in Northeast Thailand

| Year | Plantation Area (ha) | Yield (ton/ha) | Production (ton) |
|---|---|---|---|
| 1975 | 253,600 | 13.72 | 3,479,000 |
| 1980 | 725,600 | 13.79 | 10,009,000 |
| 1985 | 885,120 | 13.66 | 10,964,000 |
| 1990 | 951,473 | 13.56 | 12,407,929 |
| 1995 | 808,741 | 12.65 | 9,920,829 |
| 1996 | 773,334 | 13.91 | 10,470,301 |
| 1997 | 759,182 | 14.31 | 10,533,416 |

Sources: [OAE 1979; 1982; 1985; 1993; 1996; 1998]
Note: The production is estimated based on the yield and harvested area. The proportion of actual harvested area ranged from 91 percent in 1985 to 97 percent in 1996 of the total planted area.

ensure the farm return. This means that the crop can be left out in the field without taking harvest until the farmer is satisfied with the price for his crop. Next crop of cassava can be planted right after the harvesting.

Geographically, Thailand can be divided into four regions: the North, Northeast, Central and South region. The northeast region is the largest cassava grower among the four regions. The region constitutes about 62 percent of the total cassava plantation area and about 70 percent of the total cassava production in the country [OAE 1996]. The region has experienced a tremendous increase in cassava plantation area from 1975 to 1990 with an annual average of 46,525 ha. Since 1990, the total cassava plantation area has been decreasing slowly with an average rate of 27,470 ha per year (Table 1).

Crop area monitoring is important from the agricultural planning point of view. In Thailand, the annual agricultural statistical data on crop acreage, production and yield are prepared by applying statistical projection techniques on the field information collected through sampled interviews. The process of data compilation and report production involves quite long time, at least six months. Early availability of these data can be valuable for several purposes, one of these being the agricultural trade for export and estimating the revenue.

### I-2 *Satellite Remote Sensing and Geographic Information Systems*

Satellite Remote Sensing (SRS) has been applied in several instances of natural resources monitoring, such as wetland vegetation monitoring [Yasuoka *et al.* 1995], deforestation monitoring [Hirano *et al.* 1995], drought monitoring [Lozano-Garcia *et al.* 1995], land use change [Pande and Saha 1994], including agricultural monitoring, such as corn, soybeans, sugarbeets area monitoring [Ehrlich *et al.* 1994], irrigated crops monitoring [Manavalan *et al.* 1995] using both the optical and microwave data.

Uses of satellite data from Advanced Very High Resolution Radiometer (AVHRR) sensor of National Oceanic and Atmospheric Administration (NOAA) satellite for crop area estimation and yield modeling have also been demonstrated by many researchers, such as Groten [1993], and Potdar [1993]. This data has also been used for crop area and yield estimates in different parts of the world, such as in the United States [Hayes *et al.* 1991], Africa [Maselli *et al.* 1992], Canada [Hayes and Decker 1996; Korporal 1993], and Europe [Benedetti and Rossini 1993].

The proportion of vegetative biomass in the area being sensed or captured in the satellite data is important for later interpretation. In crop monitoring, the stage of crop growth is thus important in terms of significant spectral responses of the features in the data. For example, in case of cassava there is higher spectral response from the cassava alone during its peak vegetative growth and lesser response during early period due to less crown cover (Fig. 1 ).

Remote sensing technique, which has been used for real-time monitoring and even for an early production assessment in many parts of the world, has not been yet operationalize in Thailand. Hence, the main objective of this study was to explore the potential of remote sensing technique to classify the cassava area and monitor the production using NOAA-AVHRR data in the northeast Thailand.

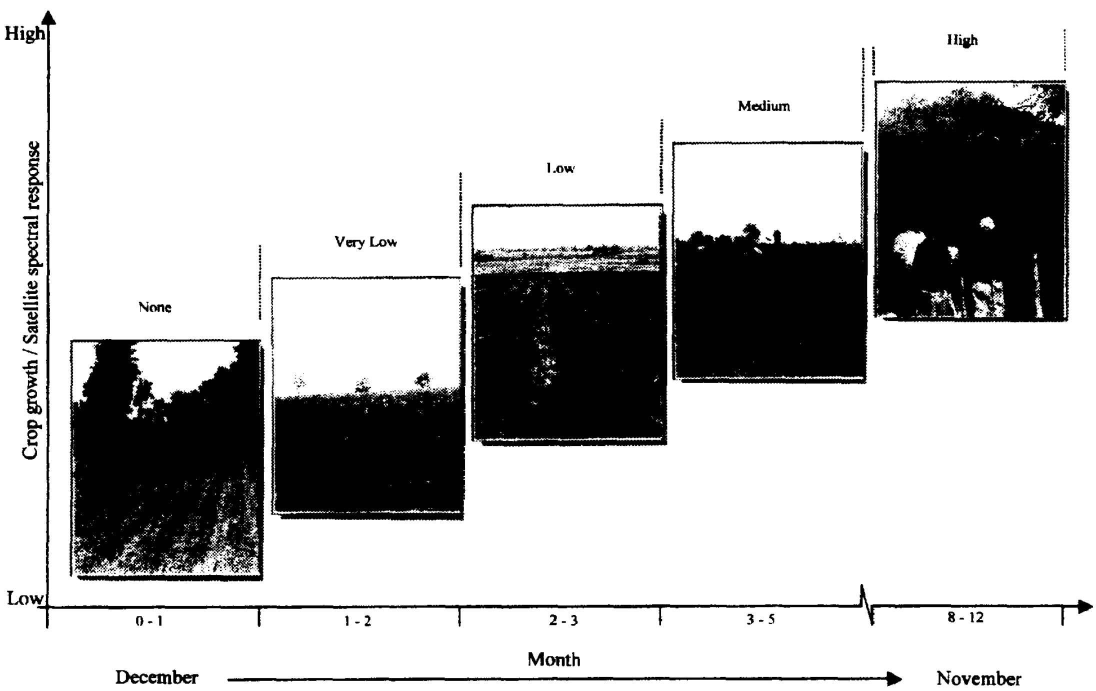


**Fig. 1** Stages of Cassava Growth and Spectral Responses in the Satellite Data

## II　Methodology

### II-1　*The Study Area*

The northeast region, located between 14°06′–18°35′ N latitude and 101°06′–105°21′ E longitude, is the largest region of Thailand with its 19 provinces covering over 170,000 km$^2$ (Fig. 2).

The climate of the area can be characterized as the tropical wet-dry climate with extreme low and high temperatures of 6.6° to 41.6° Celsius (C), respectively with the annual mean of 26.6℃ (1991–1995). There is high degree of variation in annual rainfall amount in different parts within the region. In general, the southern part of the region is drier than the northern part. During 1991–1995, the average annual rainfall amount and annual rainyday were 1,041 mm and 105 days, respectively in Nakhon Ratchasima, where as they were 2,240 mm and 137 days in Nakhon Phanom province [OAE 1996].

The topography is gently undulating all over the region except the plain areas between the Chi and Mun rivers and to the south of the Mun river. The soils are mostly light texture of sandy *Paleaquult* in the depression and *Paleustults* in the upland with low moisture holding capacity and fertility [Eiumnoh and Shrestha 1997]. However, the region is inhabited by over one-third of country's population, the income per farm family

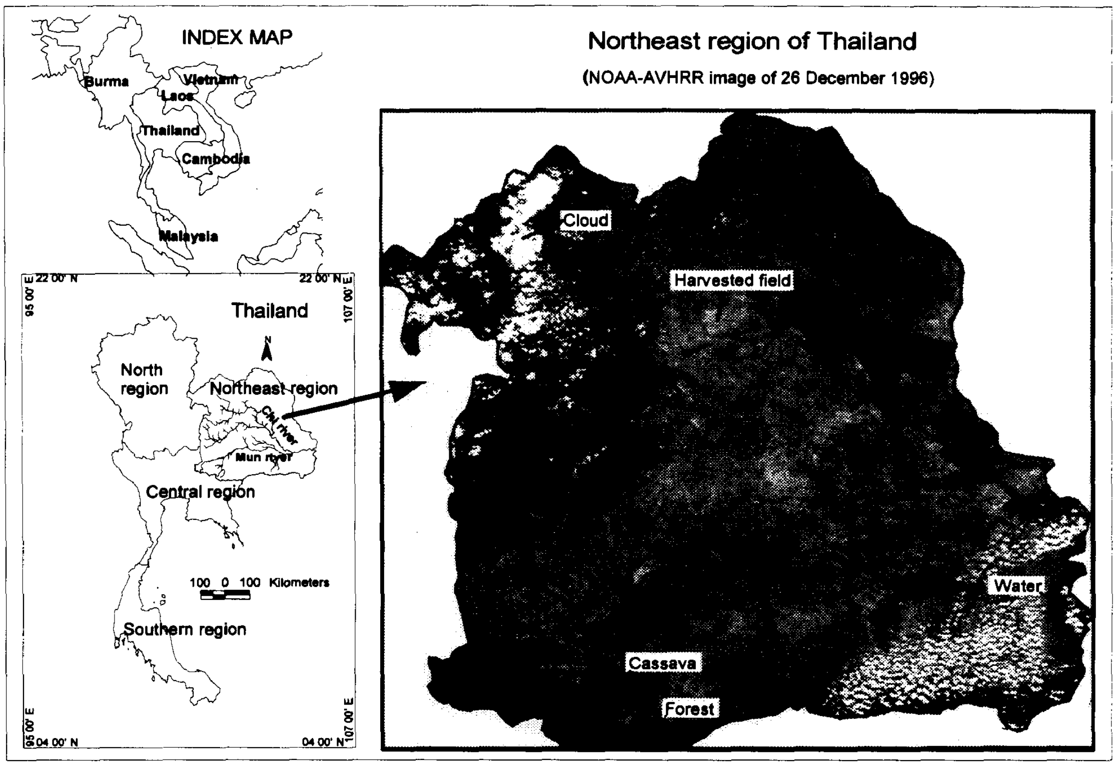


**Fig. 2**　Location of the Study Area

of 1,247 US$ in the northeast region was almost half of the country's average farm income of 2,473 US$ in 1995/96 [OAE 1998]. The unstable agricultural production is one of the major reasons for low farm income. The critical constraints that influence agriculture in the region are soil, topography, water supply and erratic rainfall.

### II-2 *Data Types*

The basic data sources were NOAA-AVHRR data acquired by NOAA-14 satellite, existing topographic maps (scale 1: 250,000; The Royal Thai Survey Department, Bangkok, 1984), land use map of 1993 (scale 1: 250,000; OAE, Bangkok), soil map (scale 1: 500,000; Soil Survey Division, Bangkok, 1982), and the published agricultural statistics. The field surveys in all the provinces of the region were conducted to carry out ground truthing for cassava cultivation and verify the land use map.

The baseline spatial database on province boundaries, land uses and soil types were prepared by digitizing the required information from the above-mentioned base maps using PC Arc/Info software.

The AVHRR senses in five wavebands ranging in the visible (band 1, $0.58-0.68\,\mu$m), the near infrared (band 2, $0.725-1.10\,\mu$m), and thermal infrared (band 3, $3.55-3.93\,\mu$m; band 4, $10.5-11.5\,\mu$m; band 5, $11.5-12.5\,\mu$m) regions of the electromagnetic spectrum at a nadir pixel resolution of 1.1 km by 1.1 km [Kidwell 1995]. Many of more recent studies have utilized the Normalized Difference Vegetation Index (NDVI), a ratio of reflectance in the near infrared and red wavelengths of the spectrum [Robinson 1996]. The AVHRR data are suitable for macro-assessment and monitoring of land cover status and their change patterns in near real time basis [Giri and Shrestha 1995]. One of the major advantages of the data is its synoptic coverage as one scene of AVHRR data can cover the whole country of Thailand, which otherwise require about 12 full scenes of Landsat Thematic Mapper (TM) to cover the northeast region of Thailand only. Table 2 reviews the strengths and weaknesses of AVHRR data.

The study employs an integration of SRS, GIS and other ancillary information from the field survey and secondary sources. The AVHRR data for two years period (1995 and

**Table 2** Strengths and Weaknesses of NOAA-AVHRR Data

| Strengths | Weaknesses |
|---|---|
| 1. Synoptic coverage and hence, low data volume | 1. Coarse resolution (1.1 km at nadir) |
| 2. High radiometric resolution (10-bit) | 2. Preprocessing is time consuming |
| 3. Relatively low cost | 3. Basically a weather monitoring data, hence the methodology in handling AVHRR data for land applications is not well developed |
| 4. High opportunity for real time data due to its daily revisit | 4. LAC data has limited capability to record on-board |
| 5. Twice daily coverage and hence high possibilities of having cloud free data | 5. Data acquired in rainy season (crop growing season) has problem of cloud |

Source: Modified from Giri and Shrestha [1995]

1996) were used in the study. The data selected for the year 1995 was acquired on 25 November 1995, and for 1996 were 24 and 26 December. Unlike the microwave radar data, which can penetrate the cloud, the optical dataset has the cloud related problem during the crop growing season in the tropical region, like Thailand. Among the data acquired during the crop season for the respective years, the selection of data was made based on the minimum percentage of cloudy pixels in the data.

### II-3 *AVHRR Data Processing*

The raw AVHRR data were taken through a number of preprocessing steps before the analysis was carried out. The calibration procedures, which are adopted for AVHRR data preprocessing by the National Environmental Satellite Data and Information Service (NESDIS) were used for this study. The percentage *albedo* of visible and infrared channels was calculated and was converted to radiance value. The thermal channels were also converted to radiance values. The radiance for all channels were calculated using the channel related linearity and non-linearity calibration coefficients given for NOAA-14. As there were two date images for the year 1996, a cloud masked composite image was prepared from 24 and 26 December images.

For the geometric correction of raw images, 60 Ground Control Points (GCPs) were collected from the topographic map and then the raw images were registered to the topographic map with the help of those selected GCPs. The Root Mean Square (RMS) error accepted was less than 1 pixel at the third order of nearest neighbor transformation.

The usual technique of estimating crop area by using remote sensing is the direct estimate from classified image. The most obvious area estimator from a classified image is

$$Z_c = \frac{\mu_c}{N_{pix}} D$$

where, $Z_c$ is the area estimator, $\mu_c$ is the number of pixels classified into the land use c, $N_{pix}$ is the total number of pixels, and D is the total area [Gallego *et al.* 1993]. The image can be classified by supervised and unsupervised techniques. Supervised technique is a user control where the whole image is classified based on the user defined training areas, where as in the unsupervised technique, the pixels are assigned to the certain groups instead of user defined training areas but the threshold values for separating different classes. In the supervised technique, homogenous areas are required for selecting as the training areas. Given the land use pattern of the study area where many types of land use exists in a one sq. km. area (pixel resolution of NOAA-AVHRR), not enough areas for training the signatures were possible. Hence, an ISODATA clustering technique was used to classify the images using original bands, ratio bands and NDVI assigning altogether 40 classes which were later regrouped based on the Ward's method of hierarchical clustering technique. This method calculates means for each variable within each cluster and squared Euclidean distance to the cluster means for each case [Aldenderfer and Blashfield 1984]. The final classification map was prepared by merging the clusters which result in the smallest increase in the overall sum of the squared within cluster distance.

The result of image classification was evaluated by computing Overall Classification Accuracy (OCA), i. e. the proportion of correctly classified pixels of the total pixels of the classified image. Construction of error matrix to express the OCA is the most common technique [Lillesand and Kiefer 1994]. A sample size of 196 pixels were determined using the following formula from the binomial probability theory [Fitzpatrick-Lins 1981].

$$N=\frac{Z^2(p)(q)}{E^2}$$

where, Z= 1.96 as the normal standard deviate for the 95% two-sided confidence interval, p= 85% as the expected percent accuracy, q=100−p, and E= 5 % allowable error. The sample pixels were randomly selected for each of the classified image to construct the error matrices and then find out the correctly classified pixels with the help of available reference information, such as field information and land use map.

### II-4 *SRS/GIS Integration*

The clustering process of image classification operates on the spectral signature of the pixel of the image. It means that a pixel is classified into only one class although it contains more than one land use types. Considering the prevailing land use pattern of the area, such situation of more than one land use type within a pixel is often likely to occur. In some instances, it might also be possible that the signatures of cassava resembles with sparse forest and bushy area, which also introduces error in the classification results by not being able to distinctly separate them because of the similar signatures of different classes.

The purpose of integrating the GIS to the classified NOAA-AVHRR images was to improve the classification results obtained from image data by post-classification sorting. The topographic information and soil information are strongly correlated in determining the certain type of land use. For example, cassava is not cultivated in the lowland or soils having aquic moisture regime. Use of larger scales or resolutions GIS database, as those in this study, compared to that of NOAA-AVHRR helps to improve the result of image classification, which is solely based on the spectral signature of the pixel.

The classified images were imported to GIS, where vector layers of land use, soil map and province boundaries were overlaid. Then, a sequential masking was followed to eliminate the land uses other than cassava on the basis of soil types and land use types (Fig. 3 ). For example, in the first step, all the non-agricultural areas were masked by using land use map. Thus, all the pixels mis-classified as cassava in the non-agricultural

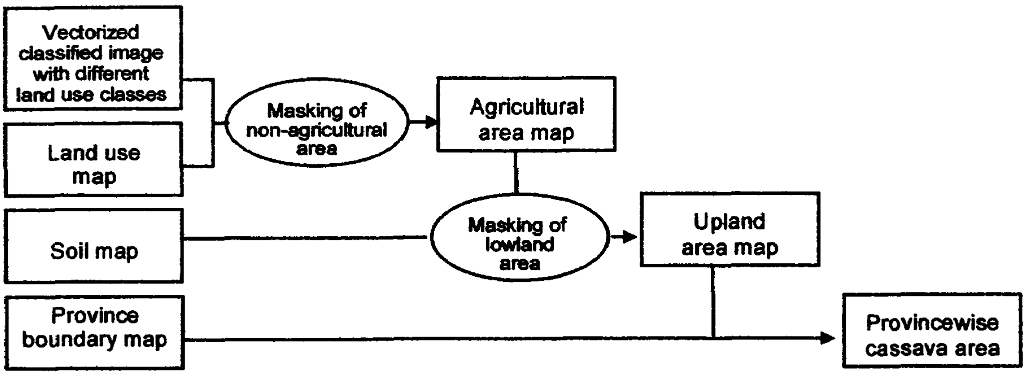


**Fig. 3**　GIS Procedure for Sequential Masking

areas were eliminated. In the second step, all the pixels, mis-classified as cassava in the lowland area (having aquic regime or paddy soil), were eliminated by overlaying the soil map. The results were reevaluated by computing OCA following the same procedure described earlier. Finally, province boundary layer was overlaid to estimate the cassava plantation area in each province.

## III Results and Discussion

III-1 *Comparison of Existing Agriculture Statistics*

The crop acreage and production of cassava have been reported regularly on the annual basis from the Thai Tapioca Development Institute (TTDI) and Office of Agricultural Economics (OAE). For the year 1995, the total cassava plantation area in the northeast region of Thailand was reported to be 748,640 ha by TTDI, where as it was 808,741 according to OAE statistics (Table 3). The differences between the reported statistics could be probably because of the method of data collection and data projection techniques of the individual organization. The technique of data collection is the interview of sample farmers or key informants by the field workers in both the cases (personal communication). Since, the organizational setup is different, in most cases it is likely that the sampled interviews with different interviewee and level of sampling lead to the generation of different statistics.

Data discrepancies can also be found with other existing information. For example, we also digitized the land use map of 1993 produced by OAE and calculated the cassava plantation area in the study area. The GIS derived cassava plantation area was much higher (1,495,248 ha) than the tabular data. It could be due to various reasons, such as map accuracy and map scale where the area is overestimated when smaller map units are masked and thus generalized during the visual classification. This shows the obvious discrepancies in the existing data generated by not only different organizations but also

**Table 3** Cassava Plantation Area in N. E. Thailand from Different Sources

| Province | TTDI Tabular Data Area (ha) | | OAE Tabular Data Area (ha) | | OAE Land Use Map |
|---|---|---|---|---|---|
| | 1995 | 1996 | 1995 | 1996 | 1993 |
| Nakhon Ratchasima | 256,000 | 260,000 | 274,542 | 275,043 | 516,630 |
| Buri Ram | 31,104 | 29,920 | 35,705 | 33,843 | 125,516 |
| Surin | 8,128 | 7,376 | 8,511 | 10,699 | 10,517 |
| Si Saket | 8,624 | 13,312 | 10,680 | 11,760 | 15,030 |
| Ubon Ratchathani | 12,480 | 10,576 | 13,504 | 14,635 | 110,308 |
| Chaiyaphum | 64,512 | 81,920 | 81,622 | 86,652 | 320,849 |
| Khon Kaen | 56,304 | 36,000 | 54,871 | 46,149 | 73,372 |
| Maha Sarakham | 28,080 | 17,760 | 27,211 | 23,590 | 16,677 |
| Roi Et | 32,256 | 17,440 | 28,374 | 25,169 | 131 |
| Yasothon | 9,600 | 6,912 | 9,958 | 8,375 | 21,722 |
| Umnat Charoen | 7,008 | 8,160 | 6,071 | 4,858 | 5,749 |
| Kalasin | 57,600 | 41,552 | 58,990 | 58,164 | 991 |
| Mukdahan | 15,504 | 18,080 | 16,051 | 16,876 | NA |
| Loei | 20,160 | 20,336 | 24,471 | 25,443 | 2,345 |
| Nong Bualamphu | 8,832 | 9,440 | 13,459 | 10,450 | 10,111 |
| Udon Thani | 55,680 | 27,632 | 59,510 | 53,575 | 182,077 |
| Sakon Nakhon | 19,584 | 8,768 | 22,653 | 20,987 | 27,204 |
| Nakhon Phanom | 6,464 | 2,976 | 5,148 | 4,162 | NA |
| Nong Khai | 50,720 | 18,656 | 57,410 | 42,904 | 56,019 |
| Total | 748,640 | 636,816 | 808,741 | 773,334 | 1,495,248 |

Sources: [OAE 1996; TTDI 1995; 1996]
Note: NA = Data not available

different data format. Such situation exhibits the need of a reliable baseline study employing a firm technique and efficient too.

### III-2 *Cassava Area Estimation*

The overall classification accuracies obtained for the classified images from the digital image processing technique alone were 74 and 78 percent for the year 1995 and 1996, respectively.

As discussed earlier, the cassava has prolonged planting and harvesting times. The prolonged harvesting period means even after the crop is at harvestable stage, can be left as such in the field for few weeks without taking harvest. It was learnt from the farmers that the yield loss due to late harvesting is not of much significance. However, the major harvesting period is from November to January. The next crop is planted right after harvesting using stem cuttings as planting materials. This implies that there can be different stages of the crop in terms of its vegetative growth at a particular point of time. Since AVHRR data is a coarse resolution (1.1 km) data, it is possible that not only different stages of cassava field can be found in the given resolution but also different land use types, which popularly can be called as "mixed pixel" condition. Such condition can be dealt by overlaying the GIS database with the classified images for the post classification sorting.

The process of post-classification sorting included the sequential mask procedure as explained in the earlier section. Fig. 4 shows an example of masking operation on how the larger scale GIS database is useful for extracting the actual cassava area from a grid or pixel otherwise classified as cassava during digital image processing.

After the post-classification sorting of the classified images with GIS database, the overall classification accuracies obtained were 77 and 79 percent for the year 1995 and 1996, respectively. The final classification results on cassava area and production in 19 different provinces of the region are presented in Table 4. Fig. 5 presents the spatial distribution of cassava in the study area for the year 1996.

Most of the cassava-growing areas are concentrated in the southern part of the region. For the year 1995, the estimated total cassava plantation area in the region was 675,724 ha ranging from a minimum of 4,829 ha in Roi Et province and a maximum of 176,525 ha in Nakhon Ratchasima province. The total fresh root production of the cassava was estimated to be 9.341 million ton with an average yield of 13.82 ton per ha based on the yield estimate of TTDI which were gathered through farmers' interview. For the year 1996, the total cassava plantation area was estimated to decrease to a total of 661,982 ha and the estimated total production was 10.552 million ton with an average yield of 15.94 ton per ha.

The farm-gate price of cassava largely dictates the time of harvesting besides farmer's own limitation of arranging resources in time. This is one of the major reasons for prolonged harvesting. In 1995, the early harvesting was taken compared to 1996 due to the higher market price of cassava roots. But in 1996, late harvesting was done due to decreasing cassava price. Thus, even the data acquired for 1995 was in November compared to December images of 1996, less accuracy was obtained for 1995 during image

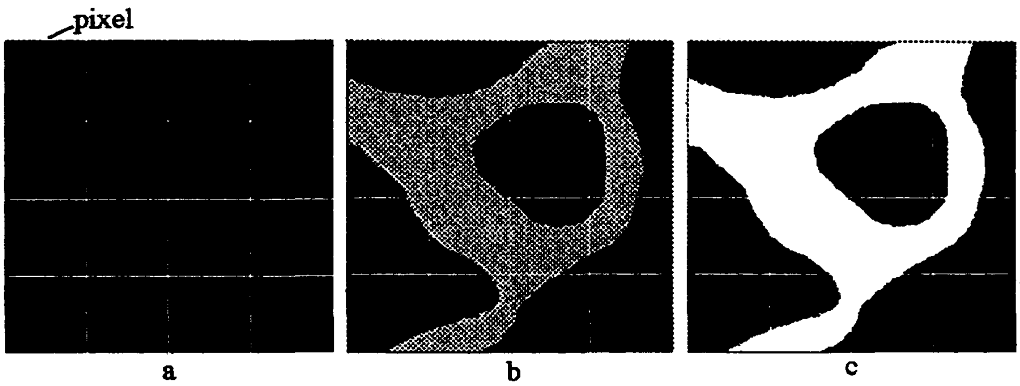


**Fig. 4** A Hypothetical Example of Coarse Resolution NOAA-AVHRR Data and Larger Resolution GIS Database during Post-classification Sorting

a ) Result of image processing where all pixels are classified as cassava
b ) Overlay of classified image and soil information, where ▒ represents lowland (paddy) soil
c ) Final result showing cassava area ■ after masking

**Table 4** Classified Cassava Plantation Area and Production in N. E. Thailand

| Province | 1995 | | | | 1996 | | | |
|---|---|---|---|---|---|---|---|---|
| | Area (ha) | Yield* (ton/ha) | Production (ton) | Area Difference** | Area (ha) | Yield* (ton/ha) | Production (ton) | Area Difference** |
| Nakhon Ratchasima | 176,525 | 13.89 | 2,451,495 | 79,475 | 269,086 | 17.50 | 4,709,012 | − 9,086 |
| Buri Ram | 44,871 | 13.98 | 627,072 | − 13,767 | 57,271 | 20.00 | 1,145,424 | − 27,351 |
| Surin | 8,474 | 14.01 | 118,755 | − 346 | 7,681 | 13.13 | 100,822 | − 305 |
| Si Saket | 12,794 | 13.79 | 176,479 | − 4,170 | 1,814 | 16.25 | 29,492 | 11,498 |
| Ubon Ratchathani | 26,500 | 13.56 | 359,415 | − 14,020 | 13,914 | 13.13 | 182,631 | − 3,338 |
| Chaiyaphum | 75,715 | 13.50 | 1,022,155 | − 11,203 | 82,843 | 14.69 | 1,216,769 | − 923 |
| Khon Kaen | 57,413 | 13.45 | 772,212 | − 1,109 | 31,919 | 13.44 | 428,918 | 4,081 |
| Maha Sarakham | 6,089 | 12.73 | 77,523 | 21,991 | 6,214 | 11.88 | 73,795 | 11,546 |
| Roi Et | 4,829 | 12.57 | 60,705 | 27,427 | 5,318 | 13.75 | 73,129 | 12,122 |
| Yasothon | 7,713 | 14.68 | 113,196 | 1,887 | 9,409 | 14.38 | 135,260 | − 2,497 |
| Umnat Charoen | 8,506 | 12.98 | 110,377 | − 1,498 | 8,576 | 15.63 | 134,008 | − 416 |
| Kalasin | 23,247 | 13.22 | 307,301 | 34,353 | 33,260 | 13.13 | 436,543 | 8,291 |
| Mukdahan | 20,682 | 12.98 | 268,359 | − 5,178 | 28,175 | 13.13 | 369,805 | − 10,095 |
| Loei | 61,540 | 14.81 | 911,568 | − 41,380 | 20,486 | 21.88 | 448,136 | − 150 |
| Nong Bualamphu | 40,530 | 14.54 | 589,470 | − 31,698 | 3,963 | 14.38 | 56,976 | 5,477 |
| Udon Thani | 33,812 | 14.54 | 491,762 | 21,868 | 27,794 | 14.69 | 408,235 | − 162 |
| Sakon Nakhon | 27,550 | 13.29 | 366,081 | − 7,966 | 21,655 | 12.50 | 270,693 | − 12,887 |
| Nakhon Phanom | 7,074 | 12.69 | 89,755 | − 610 | 2,442 | 12.50 | 30,526 | 534 |
| Nong Khai | 31,860 | 13.42 | 427,525 | 18,860 | 30,162 | 10.00 | 301,623 | − 11,506 |
| Total | 675,724 | 13.82 | 9,341,205 | 72,916 | 661,982 | 15.94 | 10,551,797 | − 25,166 |

Notes: * Yield estimates from TTDI
** Denotes the difference between TTDI's report and image classified area, e. g. in 1995, TTDI's reported area was higher by 79,474 ha for Nakhon Ratchasima but was lower by − 13,767 ha for Buri Ram province.

classification due to higher percentage of already harvested cassava fields, and thus representing the bare field.

## IV Conclusion and Further Work

The study conducted in the northeast region of Thailand for the two years indicated that NOAA-AVHRR data can be considered for the operational cassava area monitoring. However, it was somewhat difficult in deciding to which source be considered as the baseline data for the evaluation of study results due to the differences in the statistics produced by different organizations. The comparison between the findings of the study and the existing statistics from TTDI and OAE showed that the estimated cassava plantation area from the study was closer to that of TTDI with − 9.7 percent underestimated for the year 1995 and 4.0 percent overestimated for 1996. In case of OAE statistics, the estimated cassava areas were underestimated by − 16.4 and − 14.4 percent for the year 1995 and 1996, respectively.

Nevertheless, remote sensing and geographic information systems techniques are

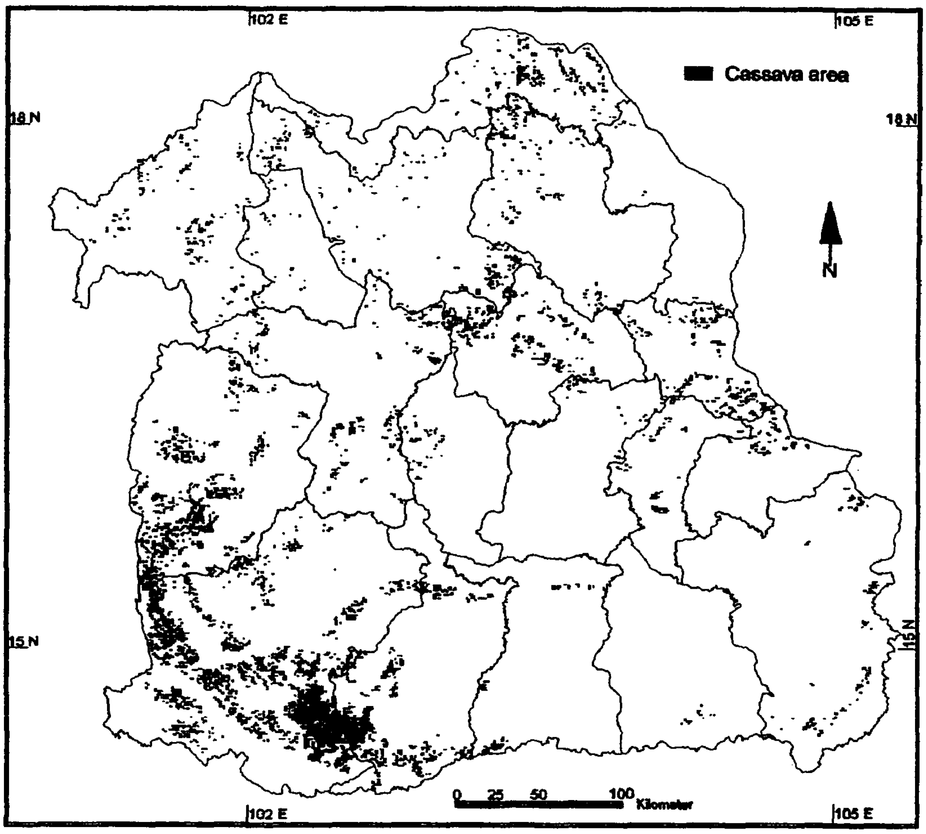


**Fig. 5** Spatial Distribution of Cassava Area in the Northeast Region of Thailand in 1996

useful tools for the crop area estimation, and certainly efficient over existing techniques for obtaining quicker and reliable results. Integration of geographic information systems at the post-classification stage of the image analysis improved the result than remote sensing technique alone in case of coarser resolution data, like NOAA-AVHRR.

Regarding the data acquisition, use of the single date data gives satisfactory result in those years of late harvesting. Considering the different harvesting time of the crop, it is desirable to use the time series data as the single date data do not represent all those cassava fields which were already harvested before the data acquired. But one of the problems in using time series data is the cloud cover in the NOAA-AVHRR data during September–October, which is the best period for data acquisition. For operationalizing the remote sensing for cassava area monitoring, the cloudfree composite image could be prepared from the several data acquired during this period (September–October), however it requires more resources towards data purchasing and processing, and which was beyond the scope of the study. Analysis of such composite image could help to correctly assess the cassava plantation areas with higher accuracy.

There are also opportunities to deal with the cloud related problem by making use of microwave remote sensing, which can penetrate the cloud and sense the earth features, but needs further studies as this technology is still in infant stage in this area of application.

**Acknowledgement**

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